Could Base Isolation be an Effective Structural System for NZ Housing?

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Te Hiranga Rū

Background

A significant portion of economic loss from the Canterbury Earthquake sequence in 2010-2011 was attributed to residential buildings. These accounted for approximately $12B of a total $40B economic losses (Horspool, 2016). While a significant amount of research effort has since been aimed at research in the commercial sector, little has been done to reduce the vulnerability of the residential building stock.

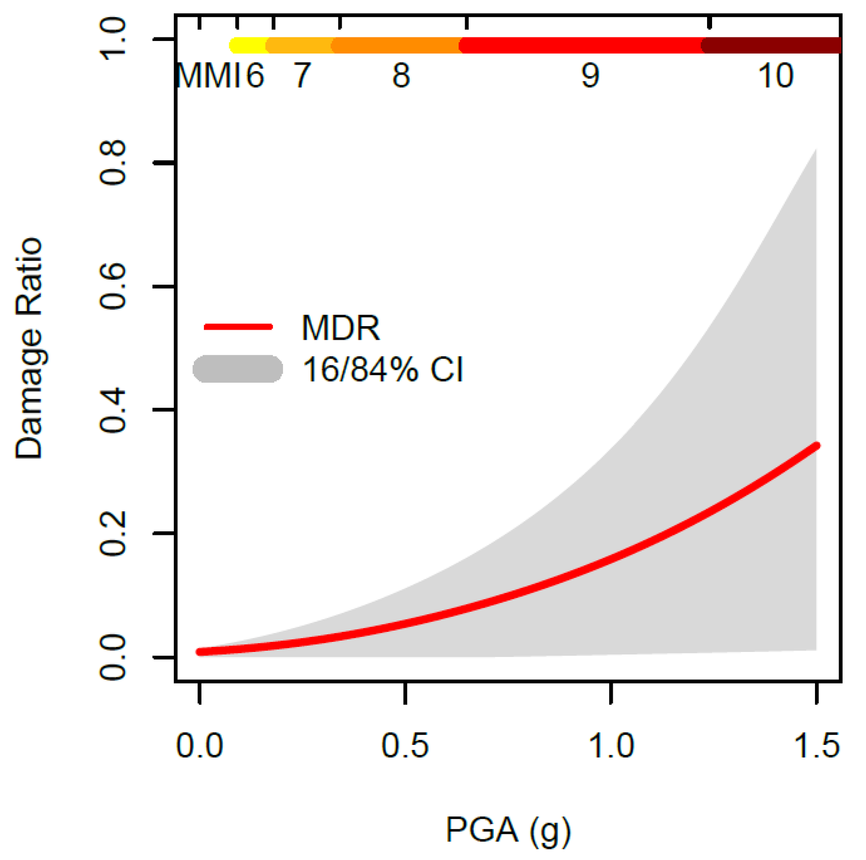

Figure 1. Vulnerability function for residential buildings. This data can be further broken down into losses due to drift and acceleration sensitive components.

Using loss data from previous New Zealand earthquake events (Figure 1), this QuakeCoRE Flagship 4 Coordinated Project will look to determine if Seismic Isolation of New Zealand residential houses is a viable method for reducing financial losses. In addition, consideration will be given to other benefits that seismic isolation may bring, including reducing the effects of downtime and negative psychological factors.

Inspiration will be drawn upon from recent work completed in Japan and the United States which showed seismic isolation to be a viable solution for timber framed buildings. Although, the effects of wind loading and the challenge of providing isolation at low intensities still prove to be challenges at the forefront of this research area.

Ultimately, the research will look to design an innovative solution for seismic isolation of New Zealand houses which is able to reduce losses in both frequent and rare earthquake events.

Challenges

A BRANZ investigation into two different types of proposed seismic isolation methods for timber houses indicated that the system would not be effective in mitigating the effects of shaking in the majority of New Zealand locations. The balance between providing enough resistance in wind storms to prevent sliding, against providing a low friction surface which can be mobilised in frequent earthquake events to reduce damage to contents will be one of the major challenges of the project.

Figure 2 shows the minimum coefficient of friction to avoid yield of the device for a number of typical houses in high wind areas. The sliding resistance of the two isolators investigated by BRANZ is lower in all cases. Therefore, we would expect the house to move in a strong wind gust. Figure 3 shows the same data but for houses in low wind areas. Again, this clearly shows that the BID (base isolation device) sliding resistance is too low in many cases to prevent movement in a strong wind gust with only low wind areas able to be considered appropriate for application.

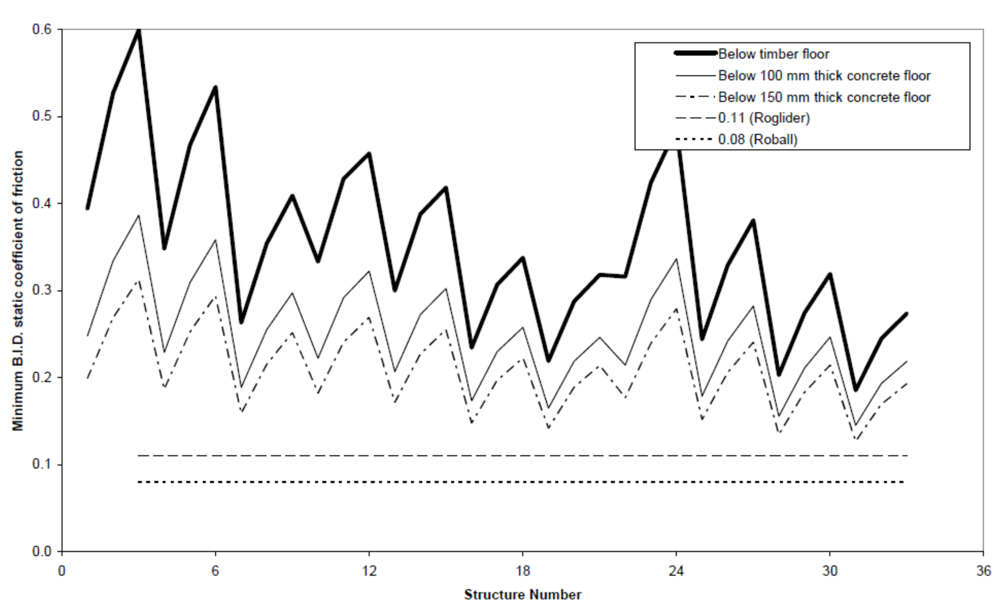

Figure 2. Minimum coefficient, μ, for isolators under a two storey house from NZS 3604 for high winds

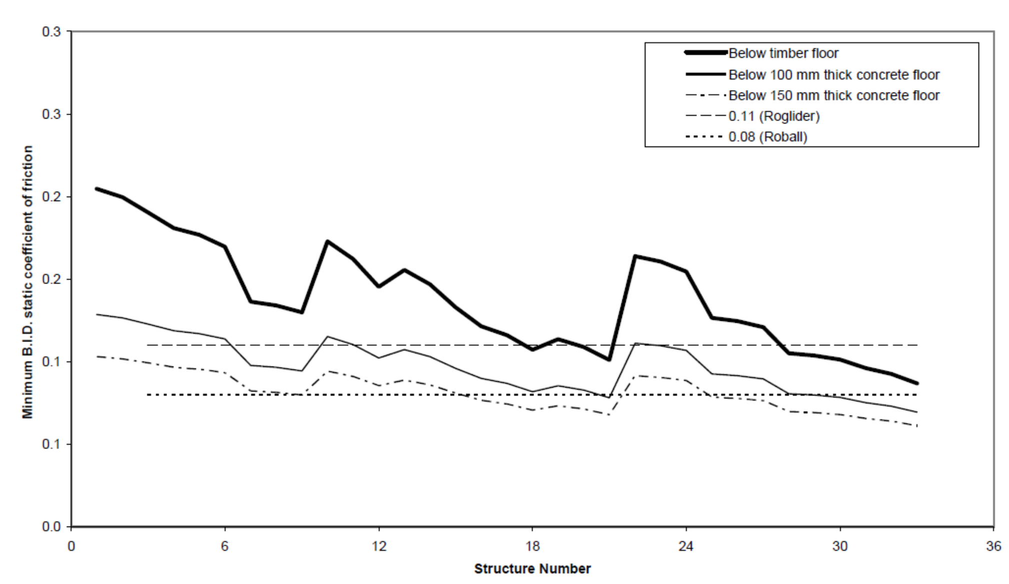

Figure 3. Minimum coefficient, μ, for isolators under a two storey house from NZS 3604 for low winds

Strategy

A preliminary assessment was undertaken to determine the change in vulnerability of standard house compared to a house with base isolation. This analysis, for now, neglects the governance of wind loading (applicable in many New Zealand locations) and simply aims to indicate the change in vulnerability for a range of different isolation solutions. The first part of the preliminary study involved investigating loss data from EQC records. The data indicates that approximately two thirds of losses are due to drift sensitive components with the remaining losses to acceleration sensitive components. Using the data in Figure 1, and by determining the relationships between drift/acceleration and PGA (similar to Figure 7 and 8), the relationship between loss and drift/acceleration was determined for standard timber framed houses (Figure 4).

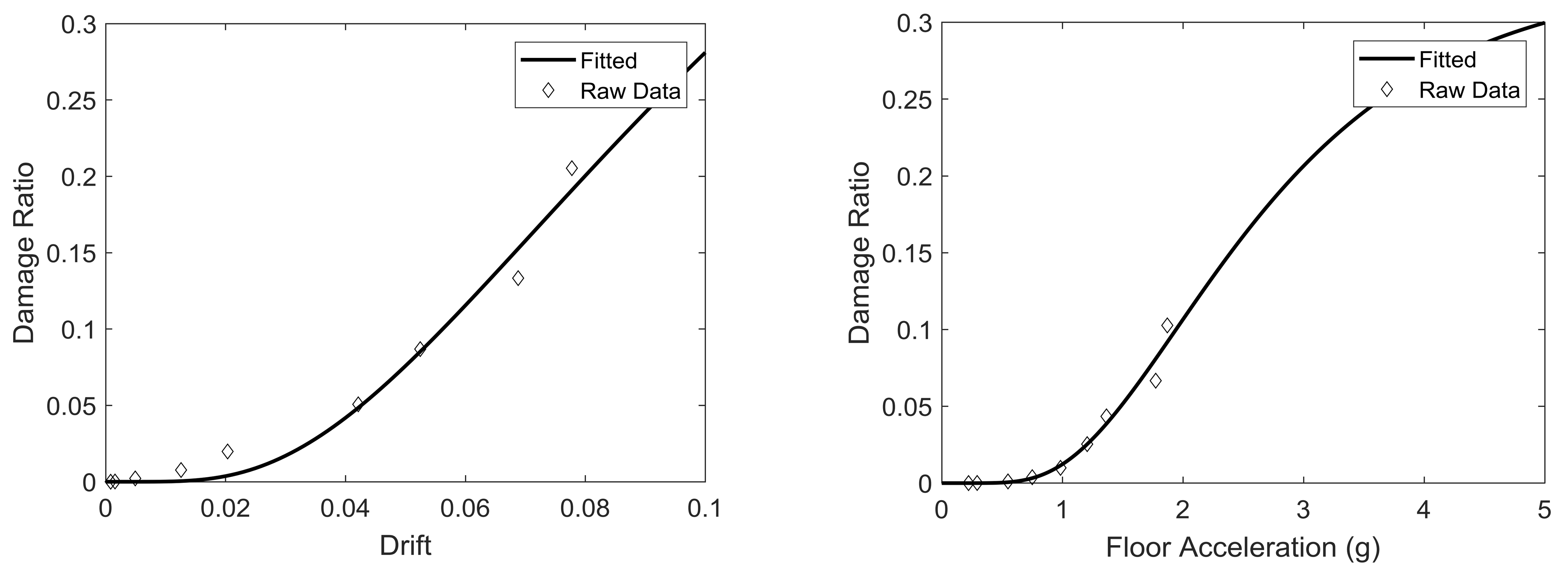

Figure 4. Loss vs Drift (left) and Loss vs Floor Acceleration (right) for a typical fixed-base timber house. Two thirds of the losses are assumed to be attributed to drift sensitive components with the remaining losses to acceleration sensitive components.

Next, a simplified model incorporating various isolation parameters for lead rubber bearings and friction pendulum devices was created. The isolator hysteresis was modelled as bi-linear spring (IHYST = 2 in Ruaumoko) and a Wayne Stewart Pinching Hysteresis was used for the house spring. Isolator parameter values are shown in Table 1 . The simplified model shown in Figure 5 was then subject to nonlinear time history analyses using ground motions determined from a PSHA for Wellington sites.

Table 1. Lead Rubber Bearing (LRB) and friction pendulum (FP) Isolator Parameters for the simple building models.

Model Type	Model N°	μ_{FR} (FP only)	T_{target} (s)	Cy	F_y (kN)	r	k_i (kN/mm)
LRB	1		3	0.1	0.981	0.05	0.0044
	2		1.5	0.1	0.981	0.05	0.0175
	3		3	0.1	0.981	0.15	0.0044
	4		1.5	0.1	0.981	0.15	0.0175
	5		3	0.3	2.943	0.05	0.0044
	6		1.5	0.3	2.943	0.05	0.0175
	7		3	0.3	2.943	0.15	0.0044
	8		1.5	0.3	2.943	0.15	0.0175
FP	9	0.2			1.962	$3.31x10^{-5}$	98.70
	10	0.4			3.924	$6.63x10^{-5}$	98.70
Rigid	11		0.2			0.05	0.9870

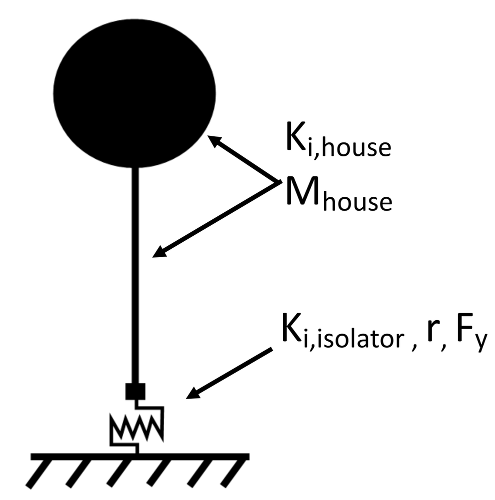

Figure 5. Simplified house model incorporating seismic isolation for the preliminary study.

The results of the nonlinear analyses are then used to determine engineering demand parameter (EDP) vs PGA relationships for each isolated house (Figure 6). At each intensity level (stripe) the median drift and acceleration is determined. Then, using the relationships already derived in Figure 4, the loss at each intensity is determined and plotted as shown in Figure 7 to derive vulnerability functions for the isolated buildings.

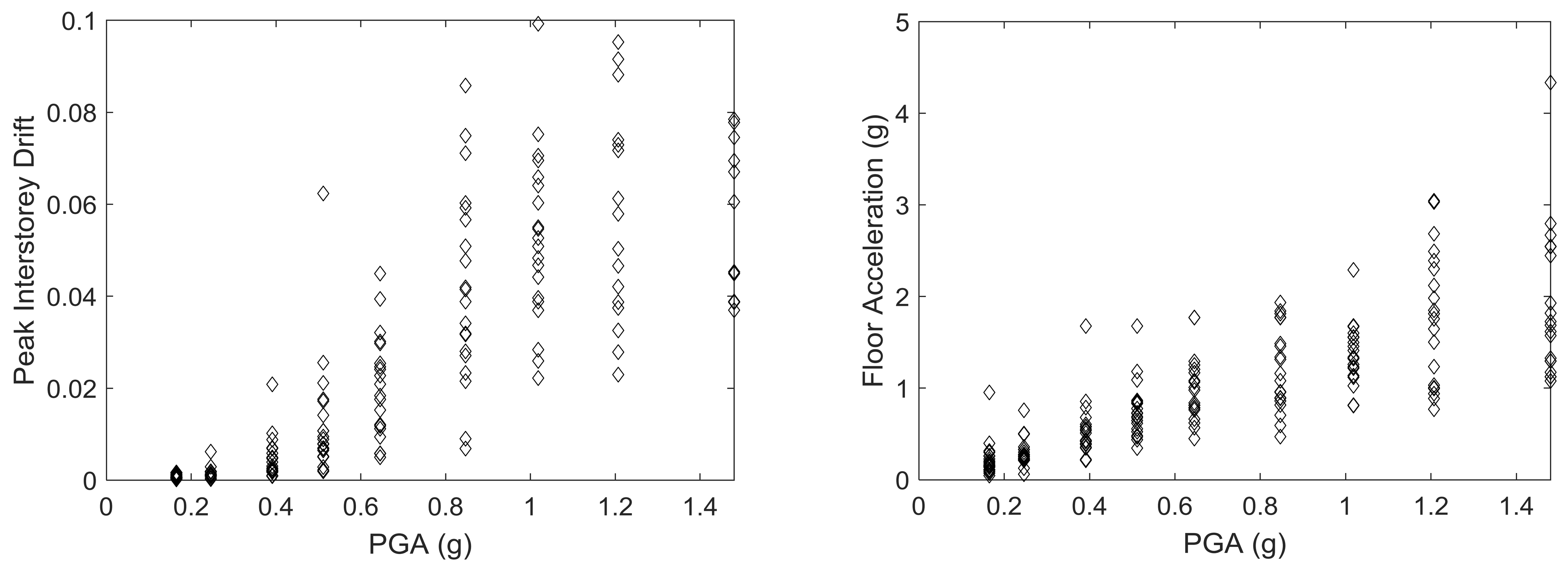

Figure 6. EDP vs PGA relationship for a given isolation system. The median EDP at each stripe/return period can be used in conjunction with the loss data in Figure 4 to produce the vulnerability curve in Figure 7.

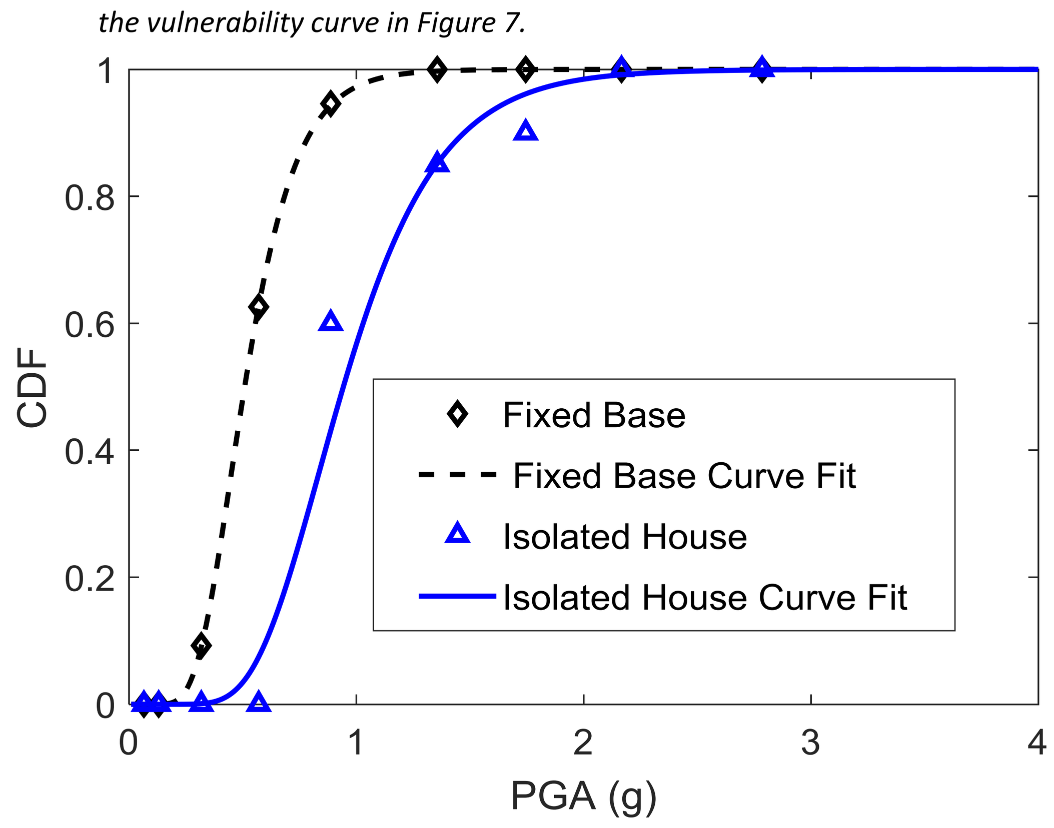

Figure 7. Vulnerability functions for the fixed base and an example isolated house. Note the curve moving to the right indicating lower expected losses for the isolated sys-

Figure 7 shows that the vulnerability curve for the isolated system moves to the right implying lower expected annual losses or scenario based loss when compared to the standard fixed base building.

This preliminary analysis is to be expanded on by incorporating more detailed house models into Ruaumoko and investigating different isolator configurations.

Further work is also to be done for modelling scenario based loss in particular using the OpenQuake platform.

Acknowledgements

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